IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Application Serial No. 10/698,592
Filing Date ..... October 31, 2003
Inventorship ..... Baumann et al.
Assignee..... The Boeing Company
Group Art Unit 1725
Examiner ..... Lynne Renee Edmondson
Attorney's Docket No. ..... BO1-0196US (formerly BING-1-1027)
Title: CLAMPING APPARATUS AND METHOD FOR MANUFACTURING

DECLARATION OF INVENTORS UNDER 37 C.F.R. § 1.131

The undersigned inventors hereby declare as follows:

1. We, John Baumann and Richard J. Lederich, are the inventors of the invention described and claimed in U.S. Patent Application Serial No. 10/698,592, entitled "CLAMPING APPARATUS AND METHOD FOR MANUFACTURING"

2. The systems and methods disclosed in the above-referenced patent application were conceived prior to April 11, 2003. Attached hereto as Exhibit A are the claims associated with the invention, which were conceived prior to April 11, 2003.

3. The invention is documented in documents and presentations prepared prior to April 11, 2003. Attached hereto as Exhibit B is a copy of confidential documentation created prior to April 11, 2003, documenting the systems and methods disclosed in the above-referenced patent application. Although the actual date is not shown in the documentation provided as Exhibit B, we declare that the actual date of creation of this documentation was prior to April 11, 2003. Attached hereto as Exhibit C is a redacted copy of confidential documentation created between April 11, 2003 and the filing of the present patent application, documenting the systems and methods disclosed in the above-referenced patent application and provided to the attorney who prepared the above referenced patent application.

4. Based in part on my own knowledge and also on information and belief, between the conception of the systems and methods disclosed in the above-referenced application (*i.e.* prior to April 11, 2003) and the filing of the above-referenced patent application on October 31 2003, testing and integration directed to reducing embodiments of the invention to practice were conducted. During this period, the activities directed to reducing the invention to practice were performed on an approximately continuous basis between the conception of the systems and methods disclosed in the above-referenced application and the filing of the patent application.

We certify that all statements made herein of my own knowledge are true, and that all statements made on information and belief are believed to be true; and further, that these statements were made with the knowledge that the making of willfully false statements and the like is punishable by fine or imprisonment, or both, under section 1001 of Title 18 of the United States Code, and may jeopardize the validity of any patent issuing from this patent application.

Signed this 22 day of November, 2006 at St. Louis, Mo.

John A Baumann

John A Baumann

Signed this 22 day of November 2006 at St. Louis, Mo.

Richard J. Lederich

Richard J. Lederich

60483

CUSTOMER NUMBER

Exhibit A.

CLAIMS

1. A clamp for securing a work piece during a manufacturing operation, comprising:

a support arranged to at least partially surround a circumference defining a work area on the work piece, the support having a first end movable relative to a surface of the work piece; and

at least one rotatable friction reducing element disposed at the first end and configured to be at least partially supported at the first end by one of a fluid pressure and a gas pressure adapted to facilitate a rotation of the friction reducing element and disposed between the support and the work piece, the friction reducing element adapted to at least partially surround the circumference and to apply a clamping pressure to the surface when the clamp is engaged with the work piece and moved across the work piece.

2. The clamp of Claim 1, wherein the support is adapted to substantially surround the circumference.

3. The clamp of Claim 1, wherein the work area includes a friction stir welding area.

4. The clamp of Claim 1, wherein the circumference surrounds and is larger than a diameter of a friction stir welding tool.

5. The clamp of Claim 1, wherein the support includes a cylinder.

6. The clamp of Claim 1, wherein the friction reducing element includes a lubricant.

7. The clamp of Claim 1, wherein the friction reducing element includes a low friction material.

8. The clamp of Claim 7, wherein the low friction material includes TEFLON®.

9. The clamp of Claim 1, wherein the friction reducing element includes a self-lubricating material.

10. The clamp of Claim 9, wherein the self lubricating material includes one of high-carbon cast iron, carbon graphite impregnates, molydisulfide impregnates, and metal polymer hybrids.

11. The clamp of Claim 1, wherein the friction reducing element includes a plurality of ball bearings.

12. The clamp of Claim 11, wherein the plurality of ball bearings are at least partially held against the surface by fluid pressure.

13. The clamp of Claim 11, wherein the plurality of ball bearings are at least partially held against the surface by gas pressure.

14. The clamp of Claim 1, wherein the friction reducing element includes a plurality of roller bearings.

15. The clamp of Claim 14, wherein the roller bearings are held in pivoting holders.

16. The clamp of Claim 1 wherein the friction reducing element includes a race of bearings.

17. The clamp of Claim 1, wherein the friction reducing element includes a plurality of pivoting and rolling castors.

18. The clamp of Claim 1, wherein the friction reducing element includes a pressurized gas adapted to apply pressure to the surface.

19. The clamp of Claim 1, wherein the friction reducing element includes a pressurized fluid arranged to apply pressure to the surface

20. The clamp of Claim 1, wherein the support includes a mechanism to move the first end towards and away from the surface.

21. The clamp of Claim 20, wherein the mechanism includes at least one of a spring, a cam, a threaded adjusting link, a pneumatic actuator, a solenoid, an electromagnetic actuator, and a hydraulic actuator.

22. The clamp of Claim 20, wherein the mechanism includes a feedback system to maintain a specified pressure against the surface.

23. An apparatus for performing a manufacturing operation on a work piece, comprising:

a manufacturing tool;

a support adapted to at least partially surround the manufacturing tool, the support having a first end positioned to move relative to the manufacturing tool; and

a friction reducing element attached to the first end, the friction reducing element adapted to at least partially surround the manufacturing tool and to apply a clamping pressure to the surface around the manufacturing tool.

24. The clamp of Claim 23, wherein the manufacturing tool includes a welding tool.

25. The clamp of Claim 24, wherein the welding tool includes a friction stir welding tool.

26. The clamp of Claim 23, wherein the support is adapted to substantially surrounding the manufacturing tool.

27. The clamp of Claim 23, wherein the support is adapted to co-annularly surround the manufacturing tool.

28. The clamp of Claim 23, wherein the support includes a cylinder substantially surrounding the friction stir welding tool.

29. The clamp of Claim 23, wherein the friction reducing element includes TEFLON®

30. The clamp of Claim 23, wherein the friction reducing element includes a self lubricating material.

31. The clamp of Claim 30, wherein the self lubricating material includes one of high-carbon cast iron, carbon graphite impregnates, molydisulfide impregnates and metal polymer hybrids.

32. The clamp of Claim 23, wherein the friction reducing element includes a plurality of ball bearings.

33. The clamp of Claim 32, wherein the plurality of ball bearings are at least partially held against the surface by gas pressure.

34. The clamp of Claim 23 wherein the friction reducing element includes a plurality of roller bearings.

35. The clamp of Claim 34 wherein the roller bearings are held in pivoting holders.

36. The clamp of Claim 23, wherein the friction reducing element includes a race of bearings.

37. The clamp of Claim 23, wherein the friction reducing element includes a plurality of pivoting and rolling casters.

38. The clamp of Claim 23, wherein the friction reducing element includes a pressurized gas arranged to apply pressure to the surface.

39. The clamp of Claim 23, wherein the friction reducing element includes a pressurized fluid arranged to apply pressure to the surface

40. The clamp of Claim 23, wherein the support includes a mechanism to move the first end towards and away from the surface.

41. The clamp of Claim 40, wherein the mechanism includes at least one of a spring, a cam, a threaded adjusting link, a pneumatic actuator, a solenoid, an electromagnetic actuator, and a hydraulic actuator.

42. The clamp of Claim 40, wherein the mechanism includes a feedback system to maintain a specified pressure against the surface.

43. A clamp for securing a work piece during a manufacturing operation, comprising:

a plurality of supports arranged to at least partially surround a manufacturing tool, each of the plurality of supports having a first end positionable relative to a surface of the work piece independent of the manufacturing tool and at least partially independent of the other supports; and

a plurality of friction reducing elements, each friction reducing element attached to the first end of each of the plurality of supports, the friction reducing elements arranged to at least partially surround a working end of the manufacturing tool and to apply a movable clamping pressure to the surface around the manufacturing tool.

44. The clamp of Claim 43, wherein the manufacturing tool includes a welding tool.

45. The clamp of Claim 44, wherein the welding tool includes a friction stir welding tool.

46. The clamp of Claim 43, wherein the plurality of supports are adapted to substantially surrounding the manufacturing tool.

47. The clamp of Claim 43, wherein the plurality of supports are adapted to coannularly surround the manufacturing tool.

48. The clamp of Claim 43, wherein the each of the plurality of supports includes a holder arranged to hold a friction reducing element.

49. A method for clamping during a manufacturing operation on a work piece, comprising:

applying a clamping force against the work piece, the clamping force being distributed over a clamping area that at least partially surrounds a work area on the work piece;

operatively engaging the work area with a manufacturing tool;

moving the work area by moving the manufacturing tool with the manufacturing tool operatively engaging the work area; and

moving the clamping area simultaneously with moving the work area, by moving the clamping area upon which the clamping force is applied along with moving the manufacturing tool.

50. The method of Claim 49, wherein manufacturing tool includes a welding tool.

51. The method of Claim 50, wherein the welding tool includes a friction stir welding tool.

52. The method of Claim 49, wherein the clamping area substantially surrounding the manufacturing tool.

53. The method of Claim 49, wherein the clamping area coannularly surrounds the manufacturing tool.

54. The method of Claim 49, wherein applying a clamping force includes clamping the work piece before operatively engaging the work area with the manufacturing tool.

55. The method of Claim 49, further comprising conforming the clamping area to match a surface contour of the work piece.

56. A method for clamping during friction stir welding, comprising:

clamping a work piece co-annularly around the circumference of a working end of friction stir welding tool; and

moving the clamping with the friction stir welding tool during friction stir welding.

57. The method of Claim 56, wherein clamping a work piece coannularly includes clamping the work piece before engaging the work piece with the friction stir welding tool.

58. The method of Claim 56, further comprising:

conforming the clamping to match a surface contour of the work piece.

59. A device for clamping during a manufacturing operation, the apparatus comprising:

means for applying clamping pressure to a work piece around at least a portion of a working end of a manufacturing tool working on the work piece; and

means for reducing friction between the means for applying clamping pressure and the work piece.

60. The apparatus of Claim 59, wherein the manufacturing tool includes a welding tool.

61. The apparatus of Claim 60, wherein the welding tool includes a friction stir welding tool.

62. The apparatus of Claim 59, wherein the means for applying clamping pressure include means for applying clamping pressure to a work piece at least partially surrounding a working end of a manufacturing tool working on the work piece.

63. The apparatus of Claim 59, wherein the means for applying clamping pressure include means for applying clamping pressure to a work piece co-annularly surrounding a working end of a manufacturing tool working on the work piece.

64. The apparatus of Claim 59, further comprising means for conforming the clamping pressure to a surface contour of work piece.

65. The apparatus of Claim 59, wherein the means for reducing friction include rolling means.

66. The apparatus of Claim 59, wherein the means for reducing friction includes pivoting means.

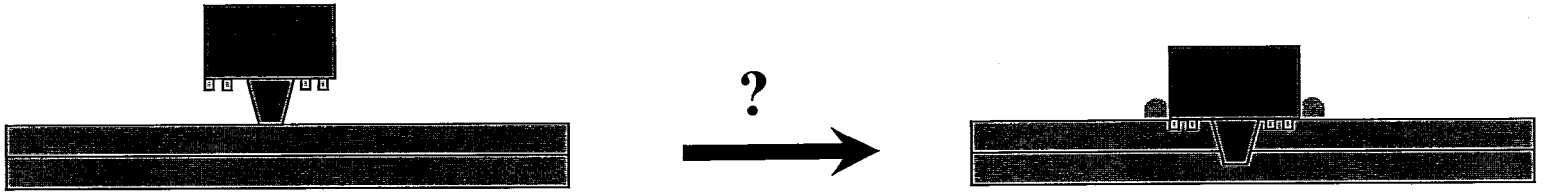
67. The apparatus of Claim 59, wherein the means for reducing friction include pressurized gas means.

68. The apparatus of Claim 59, wherein the means for reducing friction include pressurized fluid means.

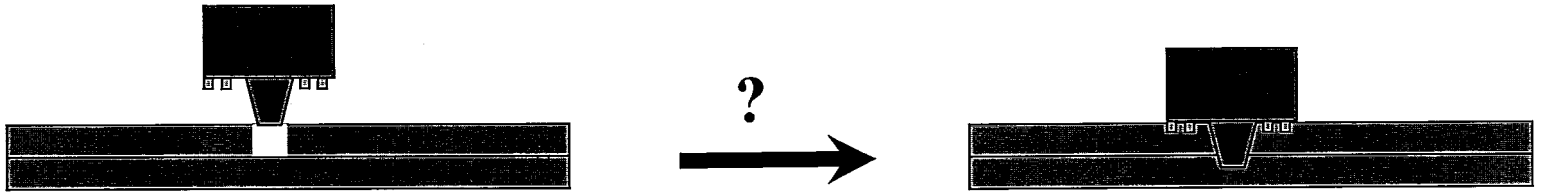
69. The apparatus of Claim 59, wherein the means for reducing friction include lubricating means.

EXHIBIT B

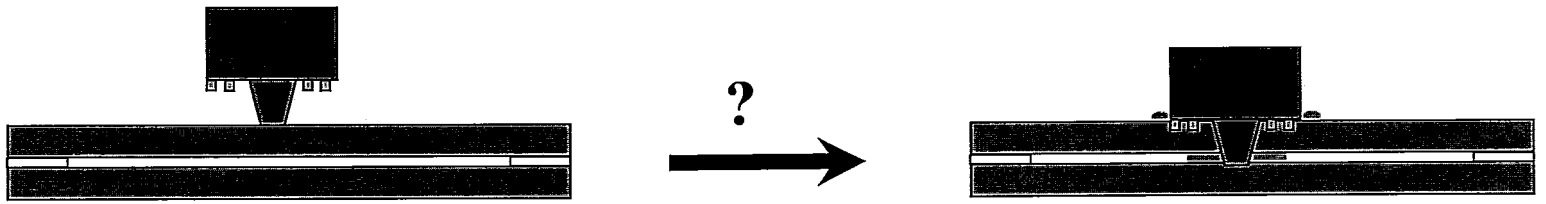
Lap Welds – What happens on plunge?



Straight Plunge into Sheets



Plunge into Hole in Top Sheet

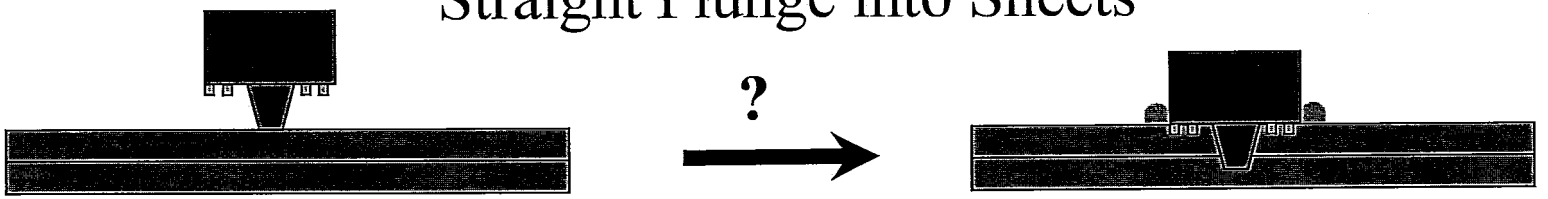


Plunge into Sheets with Gap

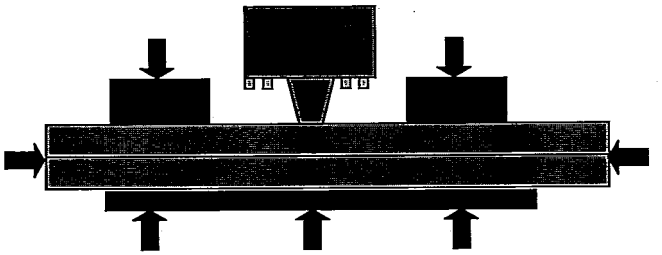
EXHIBIT B

Lap Welds – What happens on plunge?

Straight Plunge into Sheets



- **Works fine if clamping forces are high and plates can't separate.**



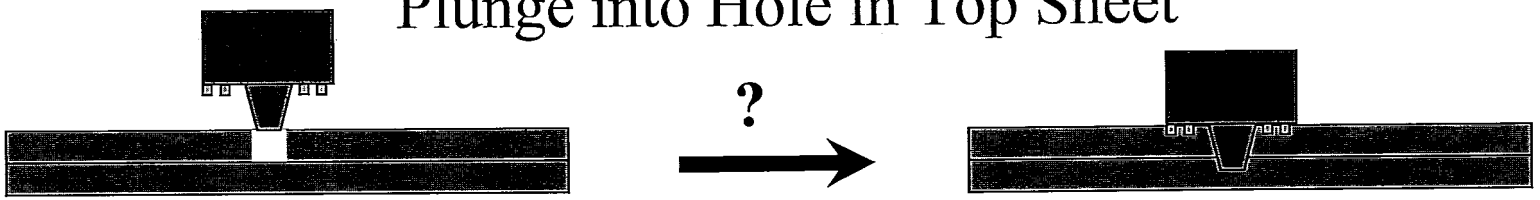
•Volume of "Flash" should equal volume displaced by pin, less that needed to fill reservoir, scroll, threads. More flash with "filled tool" than clean tool.

• "Flash on plunge" crossing weld line will impede "load" control as tool passes over it when starting travel along weld line.

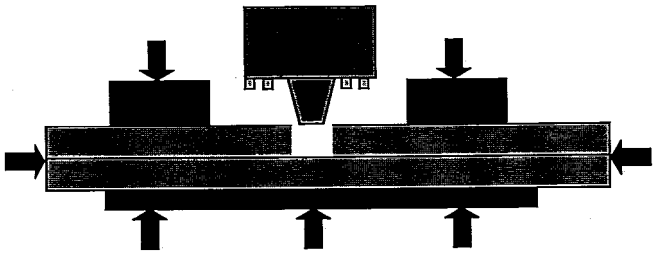
EXHIBIT B

Lap Welds – What happens on plunge?

Plunge into Hole in Top Sheet



- **Also works fine if clamping forces are high and plates can't separate.**



- **Volume of hole should be smaller than volume displaced by pin, and volume needed to fill reservoir, scroll, threads. Will be different for "clean" tool than for "filled" tool.**
- **If closely matched, little or no "Flash" on plunge, no voids at start-up.**

EXHIBIT B

Hole versus Tool Calculations for FSW0033-2007

Volume of holes:		0.125" thick plate				
Diameter						
0	12/64"	11/64"	10/64"	9/64"	8/64"	7/64"
0.000000	0.003451	0.002900	0.002397	0.001941	0.001534	0.001174
Flash for filled tool =						
0.002453	(0.000998)	(0.000447)	0.000056	0.000512	0.000919	0.001279
Flash from unfilled shoulder =			(0.000679)			
Flash for Clean Tool =						
0.001774	(0.001678)	(0.001127)	(0.000623)	(0.000168)	0.000240	0.000599

Red = void after plunge, Black = flash forms

EXHIBIT B

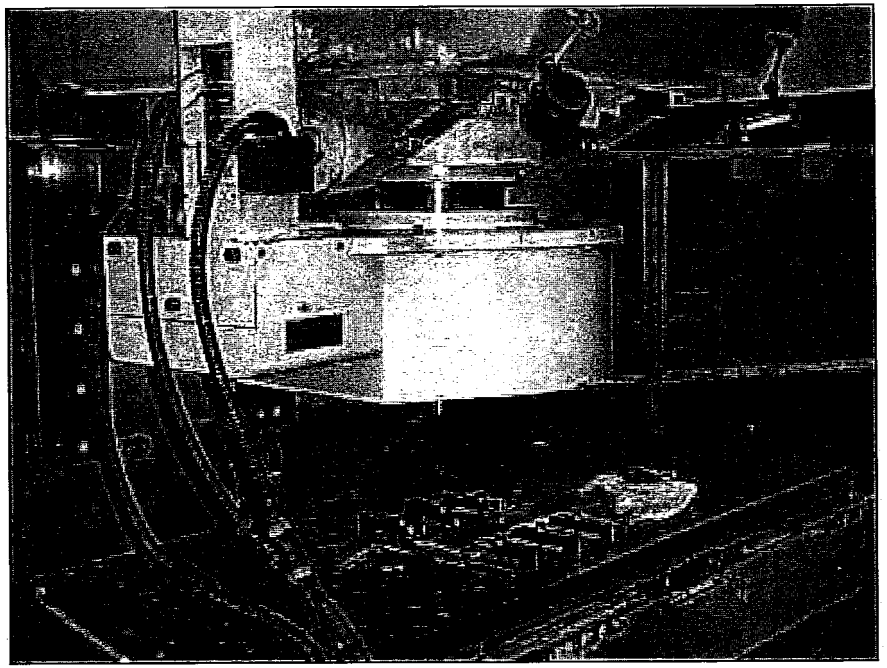
Weld Runs with Plunges into Holes

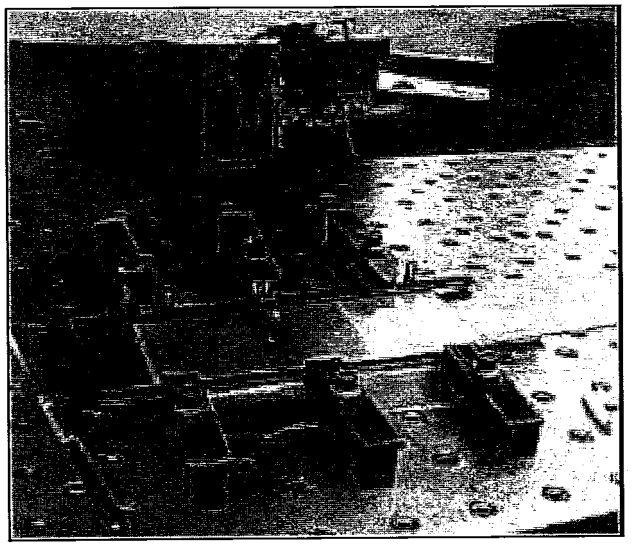
Run on Cincinnati Milicron V20 with Force Actuator, March 19, 2003
7 IPM, 1200 RPM, Z-depth = 0.160", 1200 Lbs FAC, 10+5 sec dwell
Clamping bars 5" apart

Weld Number	Hole Size	Result
437	12/64"	large void in hole
438	11/64"	smaller void
439	10/64"	yet smaller void in hole
440	9/64"	No visible void
442	7/64"	Flash at beginning
443	8/64	No void, less flash
444	None	Not lot of flash, but too close to edge
445	None	Lot more flash at start.
446	None	Flash at start. Gap at start and end
447	8/64"	No void, some flash, but gap at start!

EXHIBIT B

Photos of Set-up





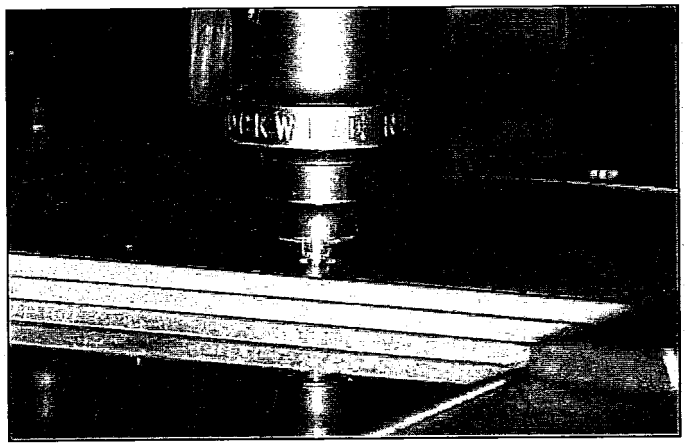
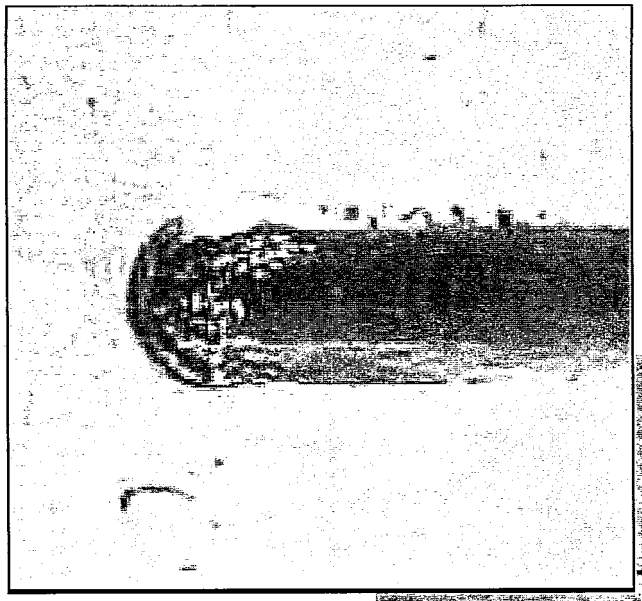


EXHIBIT B

Photos of Surface



Weld 437 12/64" large void in hole

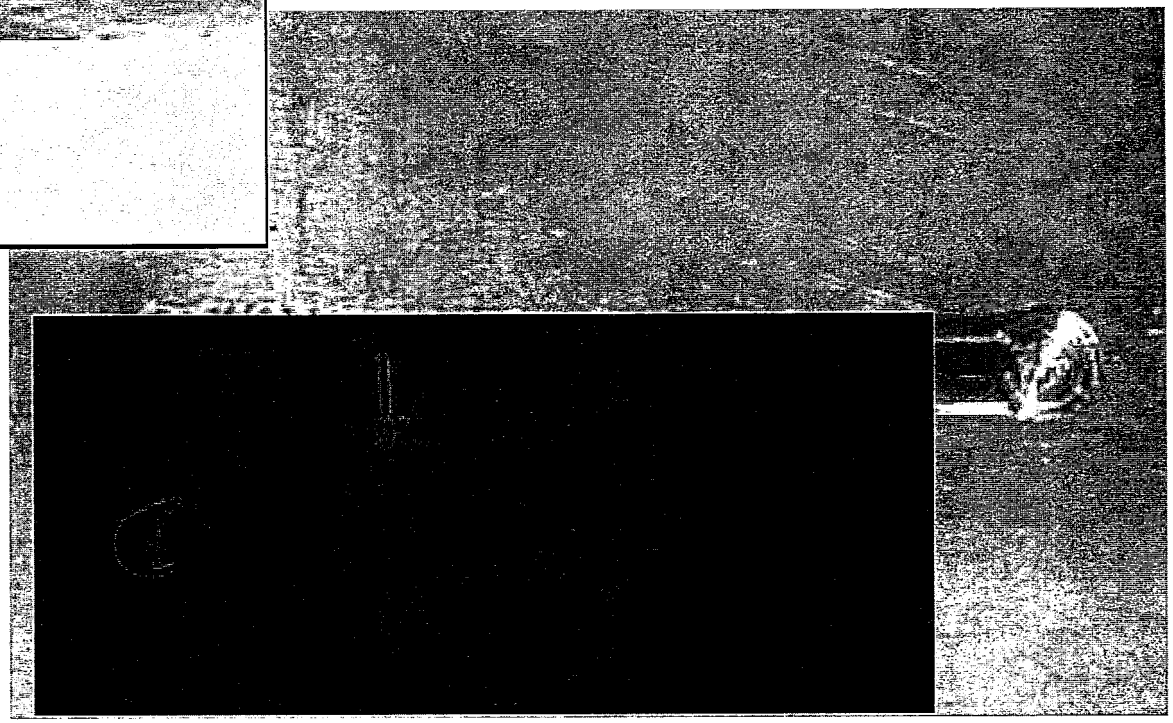
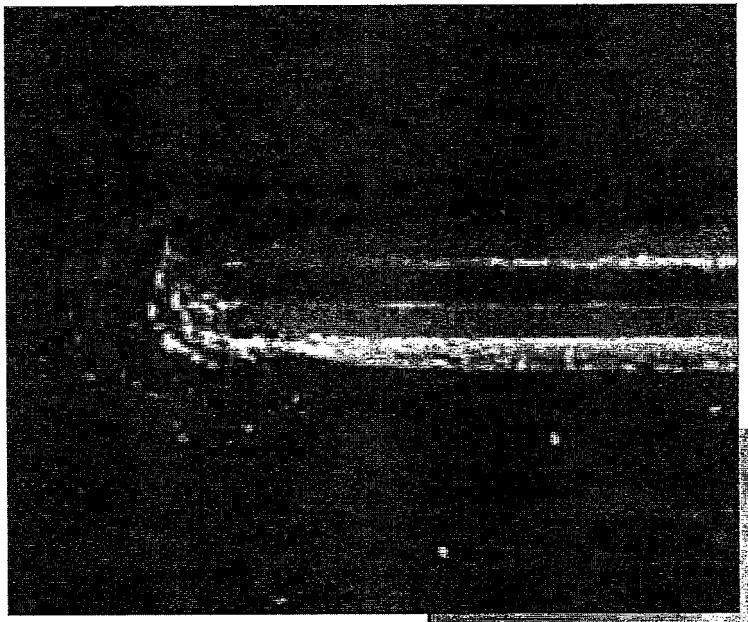
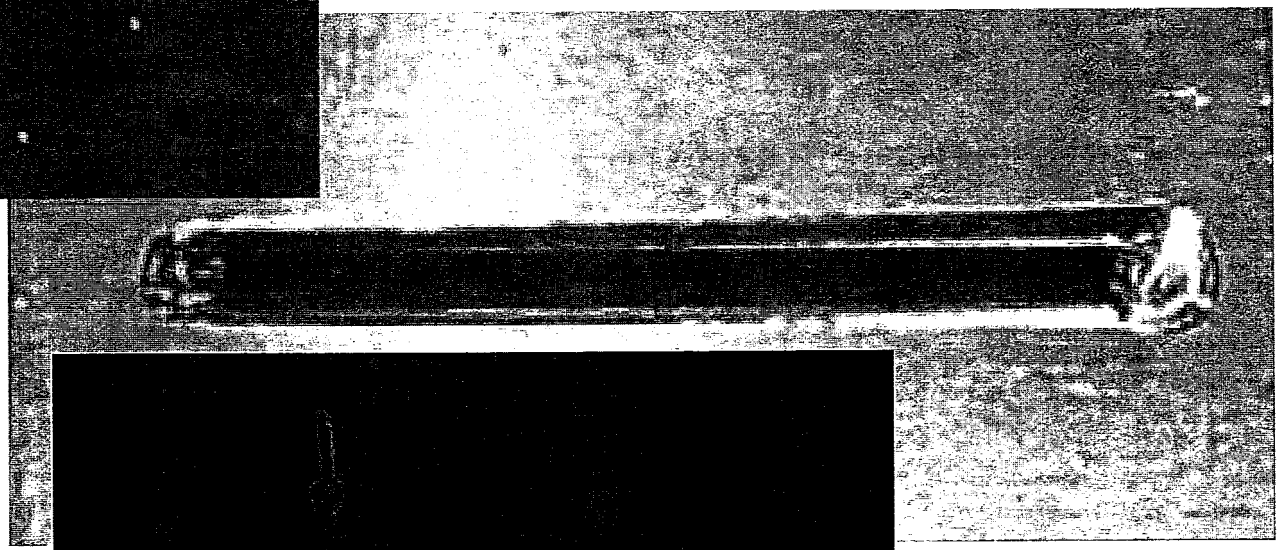


EXHIBIT B

Photos of Surface



Weld 438 11/64" smaller void



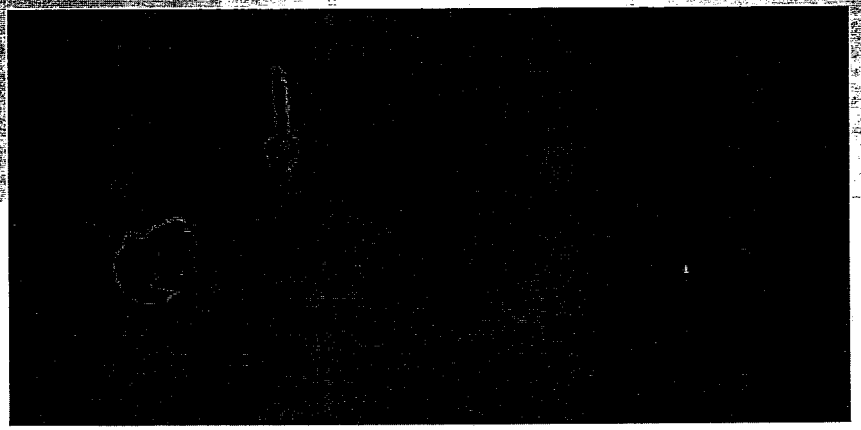


EXHIBIT B

Photos of Surface

Weld 439 10/64" yet smaller void in hole

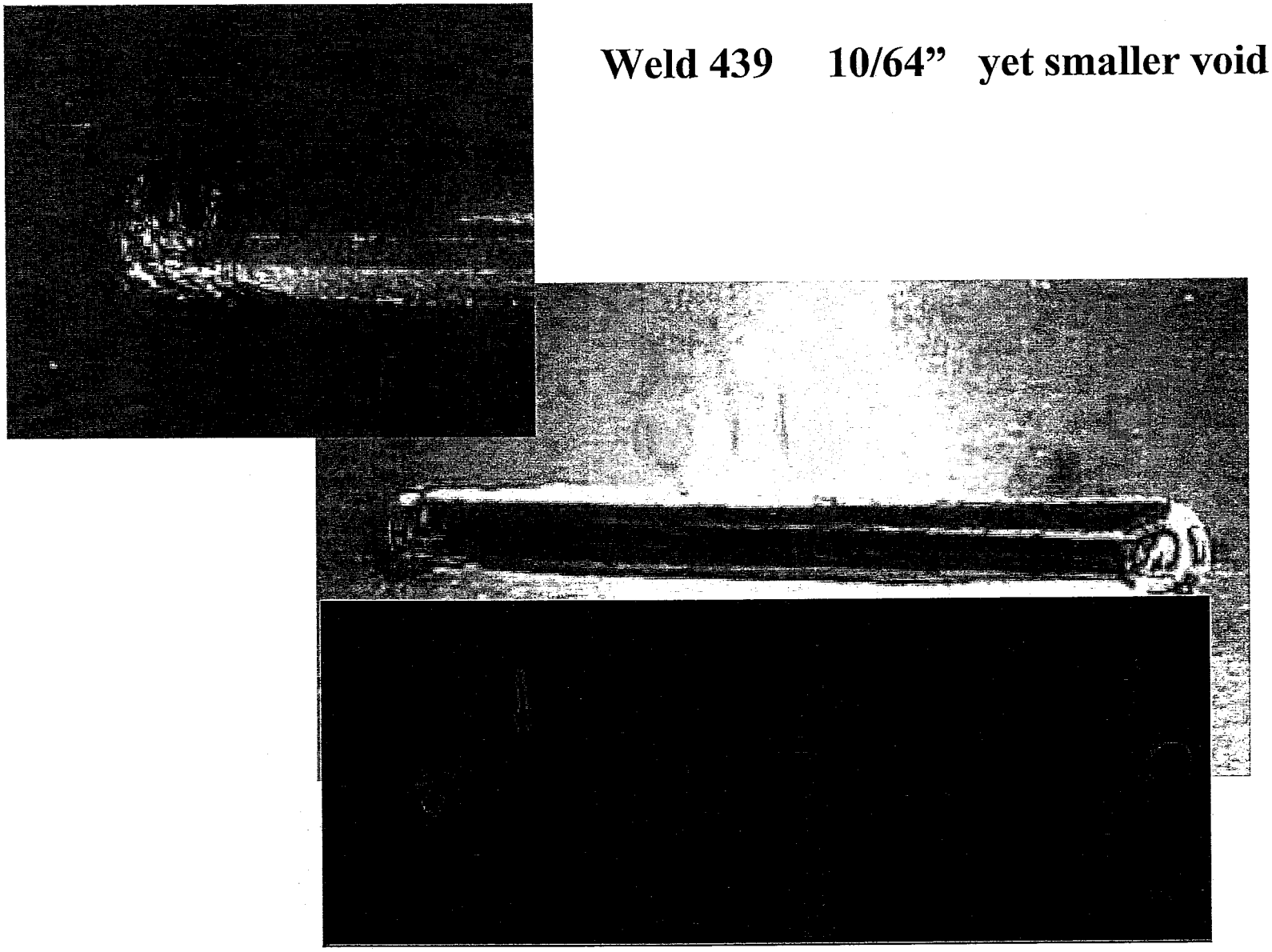
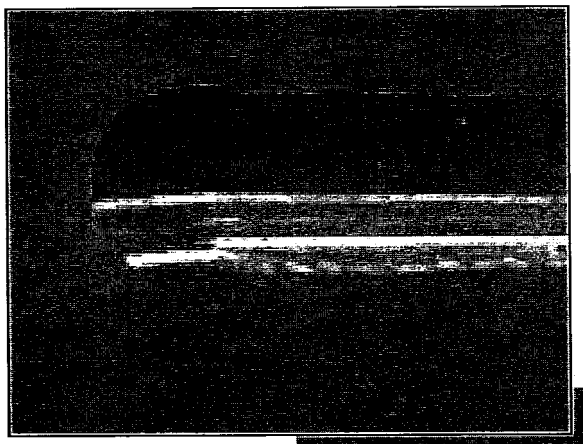


EXHIBIT B

Photos of Surface

Weld 440 9/64" No visible void



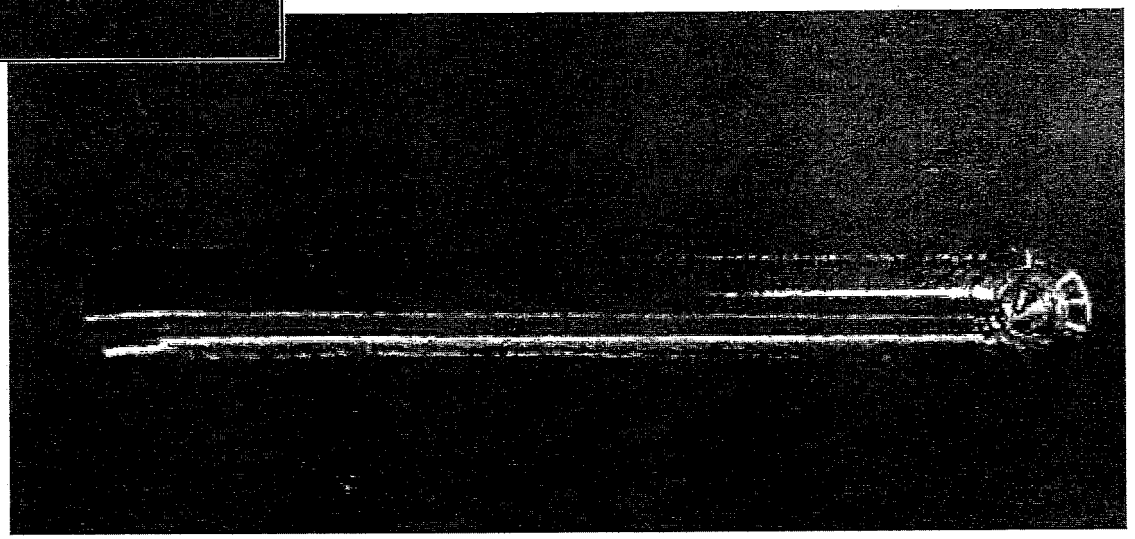
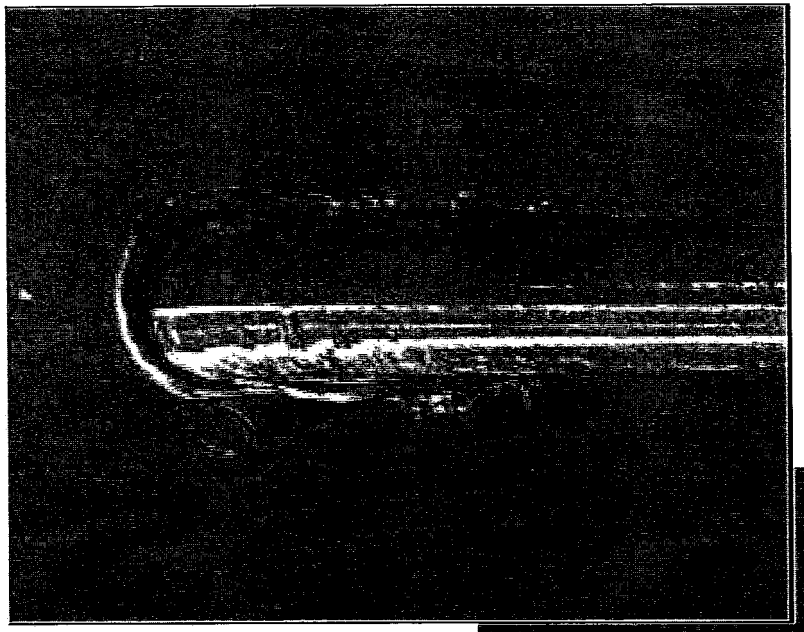


EXHIBIT B

Photos of Surface



Weld 442 7/64" Flash at beginning

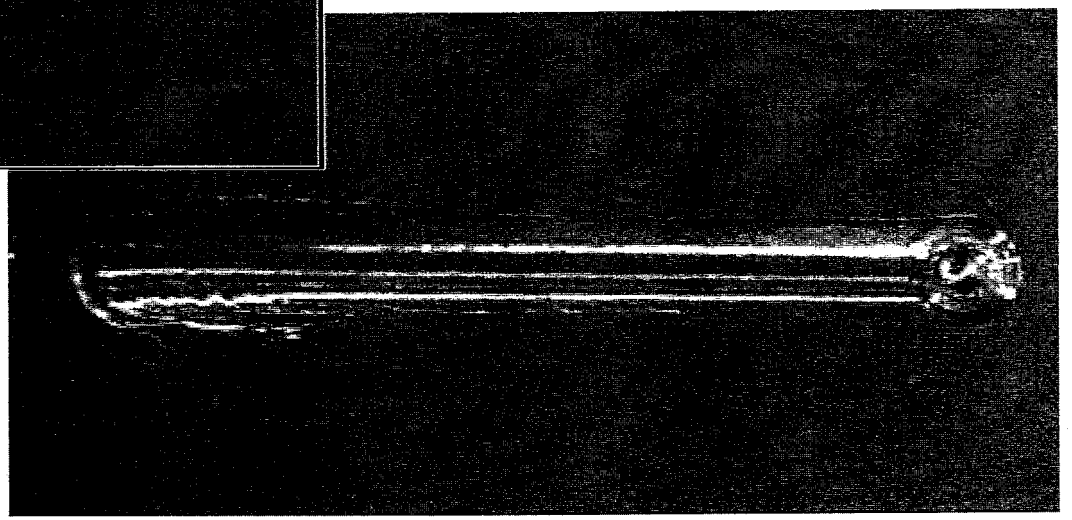
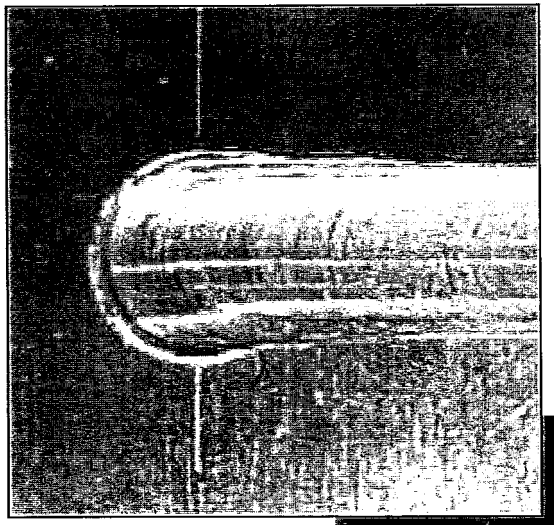


EXHIBIT B

Photos of Surface



Weld 443 8/64" No void, less flash

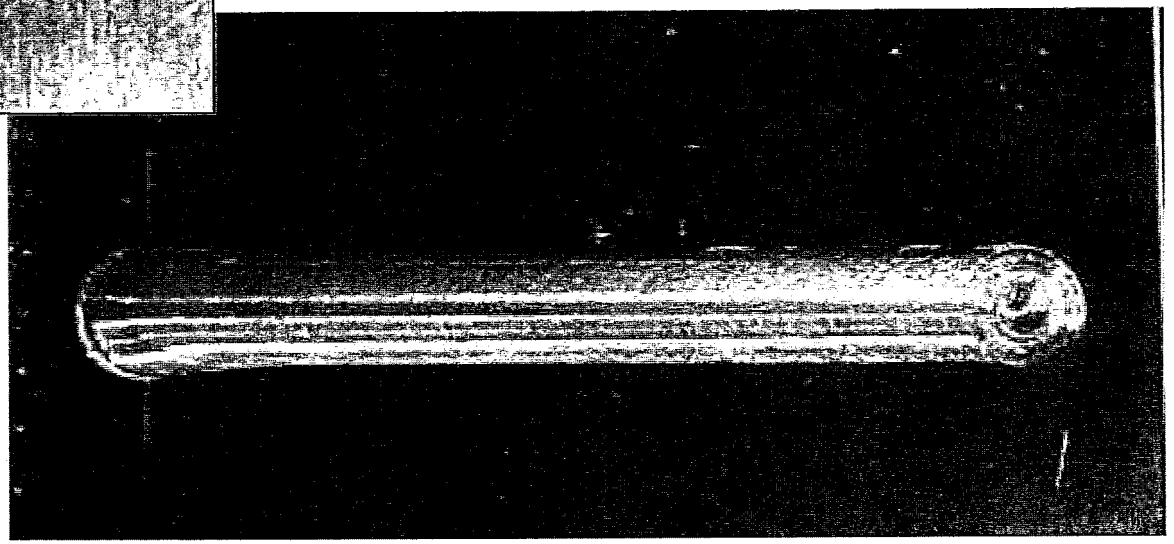
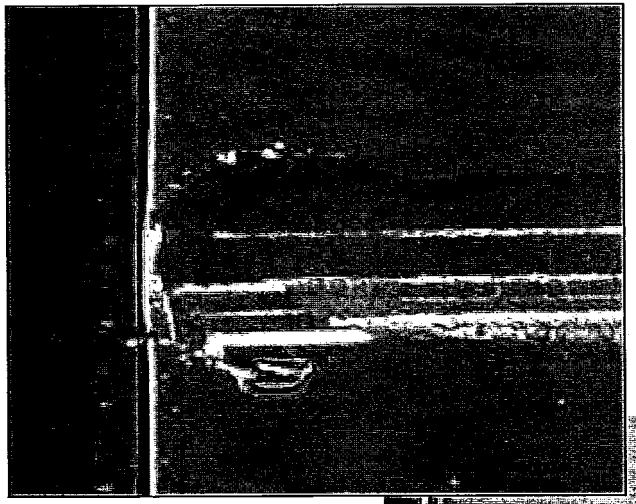


EXHIBIT B

Photos of Surface



Weld 444 **None** **Too Close to Edge, distortion**

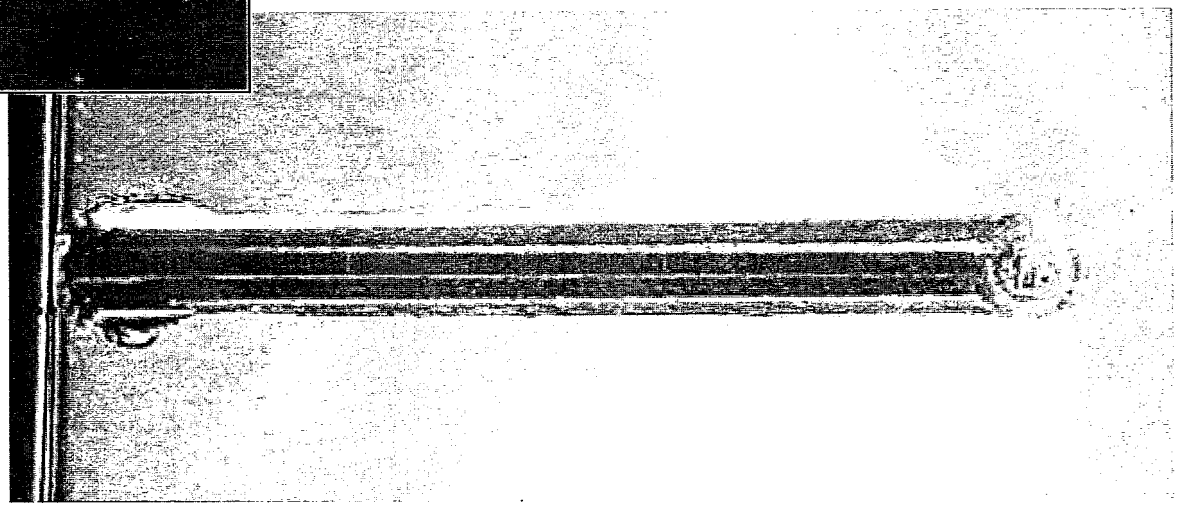
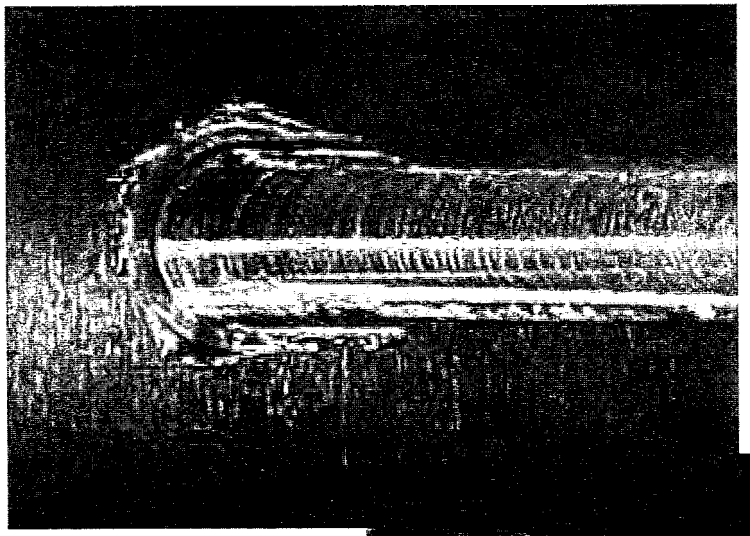


EXHIBIT B

Photos of Surface

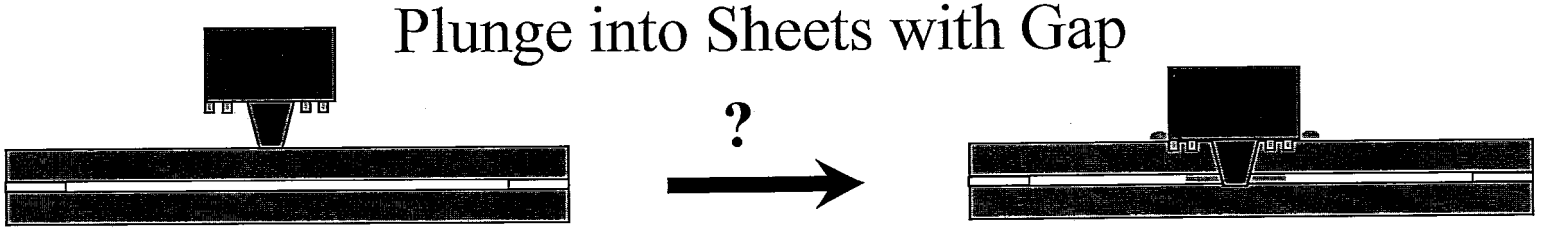


Weld 445 **None** **Lot more flash at start.**

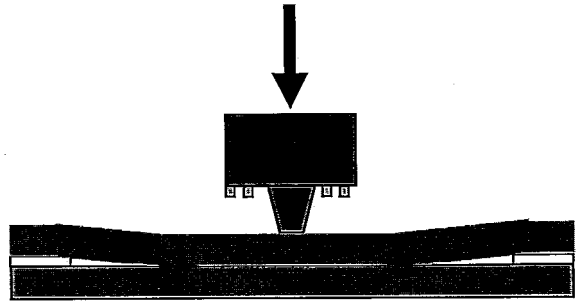
EXHIBIT B

Lap Welds – What happens on plunge?

Plunge into Sheets with Gap



- **Less than 200 pounds of load from tool required to close gap with 0.125" thick 2024 plate, 5" gap, and 0.020" shim.**

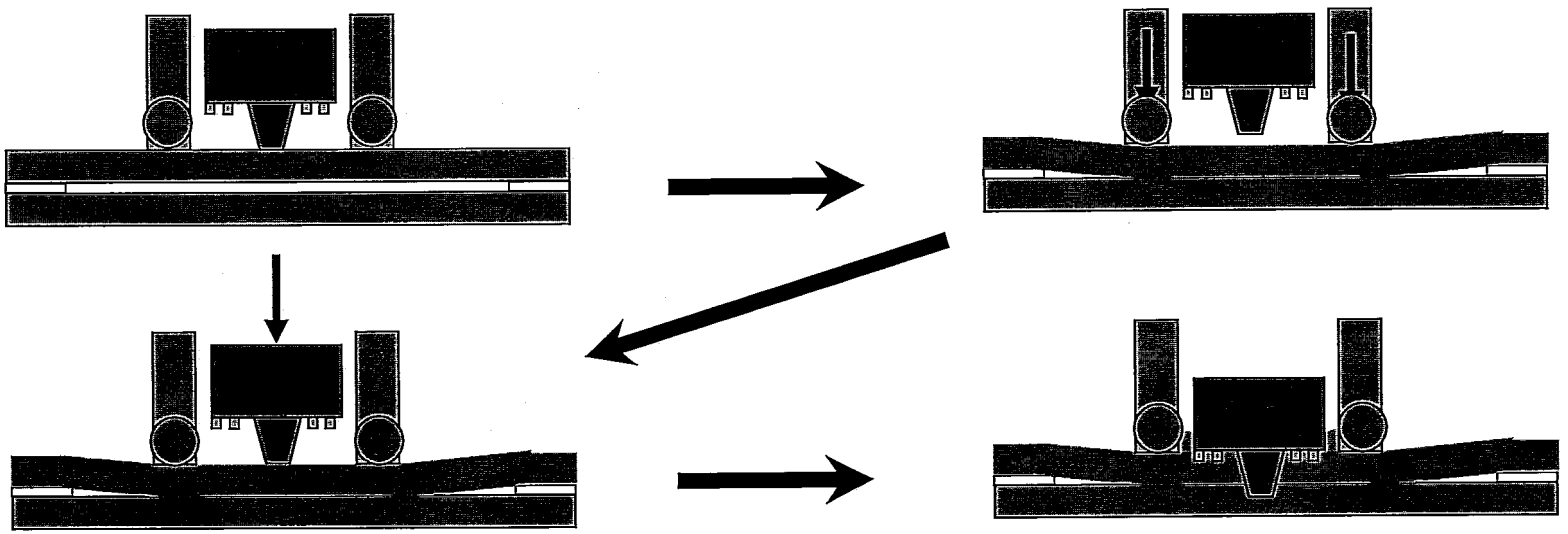


- **Expected tool load applied though pin to close-up gap – which it does – and then hoped it would stay closed during plunge, until shoulder could apply load.**

- **Haven't been able to get to work (no final gap) with or without hole, with straight plunge, or "load" control plunge - but with <u>cylindrical</u>, not conical, tool.**

EXHIBIT B

Lap Welds – What happens on plunge?



- **May be able to use co-anular, spring loaded "tool" to apply pre-load prior to plunge of fixed shoulder/pin tool.**
- **But may need to run weld with auxillary tool removed (e.g., make "spot weld" then return to do re-plunge and weld run) or run with aux tool in place**
- **Add rollers to spring-loaded tool to apply pre-load and then follow during along weld run?**

EXHIBIT B

[redacted] EXHIBIT C

BOEING®

INVENTION DISCLOSURE

[redacted]

TITLE OF INVENTION

Clamping FSW Tool For Lap Welds

THE INVENTION

Business Problem That Led to This Invention: *(A. - General description of the problem/objective; B. - Key or unique problem characteristics; C. - Prior art, i.e., prior techniques, methods, materials, or devices performing function of the innovation, or previous means for performing function of software; and D. - Disadvantages or limitation of prior art.)*

A major potential application area for the Friction Stir Welding (FSW) process is as an alternative to fastened, riveted, or bonded assembly of subcomponents into structural assemblies for airframes. Boeing is actively pursuing the development of the process for such applications, as the process has the potential for lower cost, faster cycle times, reduced tooling requirements, improved quality, and lower assembled weight. To assemble components using FSW requires that they be held in intimate contact via some mechanism that can withstand the various directional forces generated by the process that would otherwise move the components out of registration, impart defects to the welded joints, or elsewise disrupt the desired operation of making the assembly. This mechanism needs to be at once robust and of sufficiently low cost to retain the potential cost advantage of FSW assembly over other methods.

Technical Problem Solved by the Invention: *(A. Unique or Novel Features of the invention; Results or benefits of it's application; B. Advantages of innovation/software; C. Analysis of capabilities; and for software, any re-use or re-engineering of existing code, use of shareware, or use of code owned by a non-federal entity)*

Current solutions to the clamping requirements for FSW processing are generally very straightforward to achieve for simple lap joints between two flat sheets of material – as often encountered in research and development experiments. However, in welding of pieces of more complex geometry, such as with skins to underlying structural elements (ribs, keels, stringers, etc.) both shortfalls in clamping tooling and part mismatches (due to dimensional tolerances, assembly gaps, distortion of components, etc.) the requirement to keep the parts in intimate, rigid contact during FSW processing often cannot be met, resulting in welds with insufficient quality, unwanted gaps between elements, distortion and other undesirable results. Current static, localized clamping systems cannot overcome some of the forces in FSW that work to drive apart the elements to be joined. This has proven to be a particularly difficult problem for lap joints between top sheets of material (e.g., "skins") to underlying elements that are narrow in width (e.g., such as "ribs"), thereby restricting the type and effectiveness of static clamping mechanisms. Even conventionally used "roller" systems that proceed, trail or parallel the sides of the weld pathway, are unlikely to be of assistance in providing sufficient clamping due to the distance from the actual weld tool or the lack of an underlying structural element to react the clamping load.

I have read and understood all pages of this invention disclosure that I have signed or initialed. PLEASE PROVIDE ALL INFORMATION ON THE FIRST PAGE, THE REST MAY BE INITIALED AND DATED.			
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EXHIBIT C

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INVENTION DISCLOSURE

[redacted]

TITLE OF INVENTION

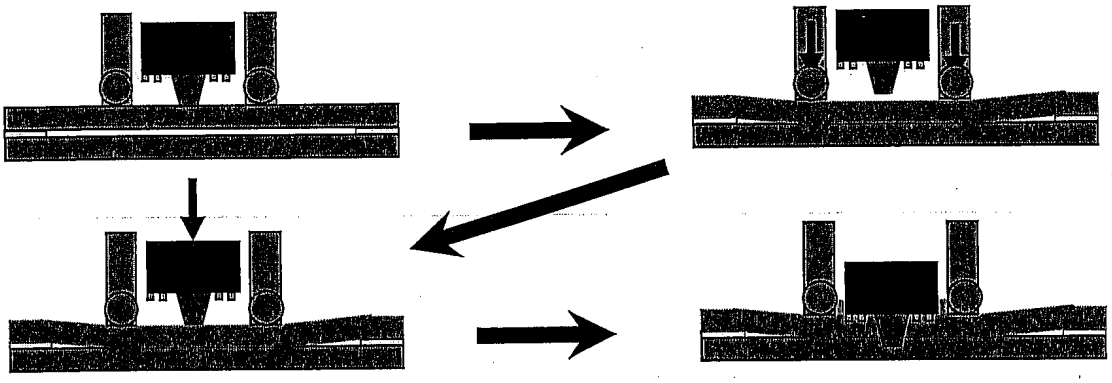
Clamping FSW Tool For Lap Welds

The envisioned invention provides a mechanism to achieve the required clamping mechanism in sufficiently close proximity to the weld tool and at the appropriate timing of the welding process to eliminate these technical difficulties of obtaining quality lap welds.

Brief Invention Description: ***(A general description of the innovation which describes its capabilities, but does not reveal details that would enable duplication or imitation of the innovation)***

The invention envisions the use of a co-annular, spring-loaded "tool", established around the actual FSW tool, to provide a pre-load clamping force to the top surface, sufficient to overcome any gaps between the top surface and underlying element, prior to the application of the plunge of the FSW tool into the materials to be joined. The welding is then accomplished with the parts in full registration. Welding could either be done using this method on a spot by spot basis, or in a continuous fashion, if the clamping tool is provided with a mechanism, such as roller bearings, to travel along with the FSW tool. The latter method provides for the clamping tool to continue to impart a clamping load to any other area along the weld pathway where, for any of a number of reasons, an encountered gap between elements is overcome by the clamping load.

The following figure, taken from the original description of the concept, illustrates the sequence for initiating a weld, made from the perspective of a cross-section perpendicular to the weld pathway. The circles on the vertical members of the co-annular clamping tool represent the bearing mechanism for following along the weld pathway while providing the clamping force.



Detailed Description Of the Invention (Optional):

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